

MONTE FOR ORBIT DETERMINATION

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2. It has been successfully deployed across four broad mission configurations: orbiter, cruise, irregular body, and tour.

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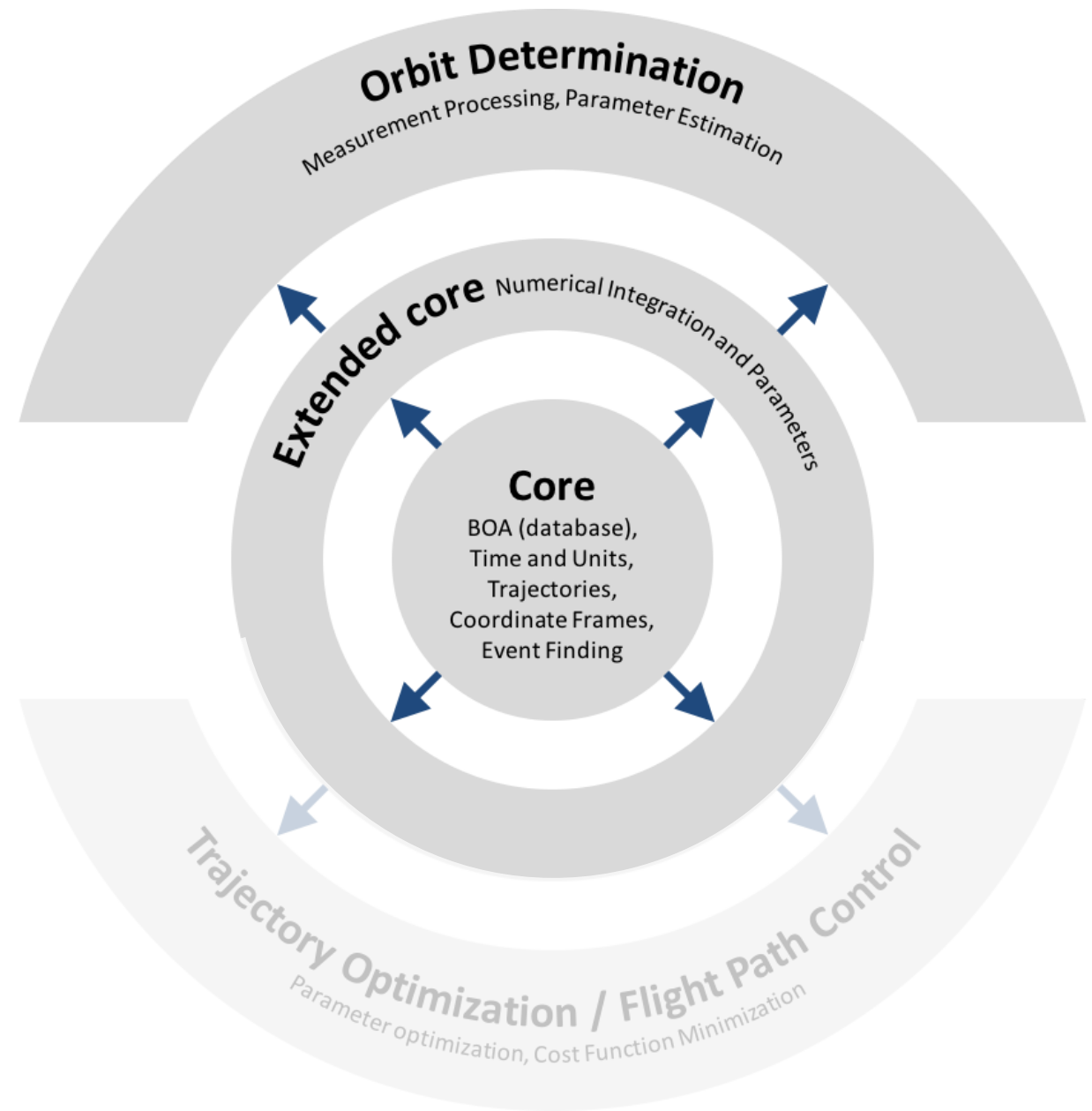


**ASTRODYNAMIC
MODELING**

**+ MEASUREMENT
PROCESSING**

**+ PARAMETER
ESTIMATION**

**= ORBIT
DETERMINATION**

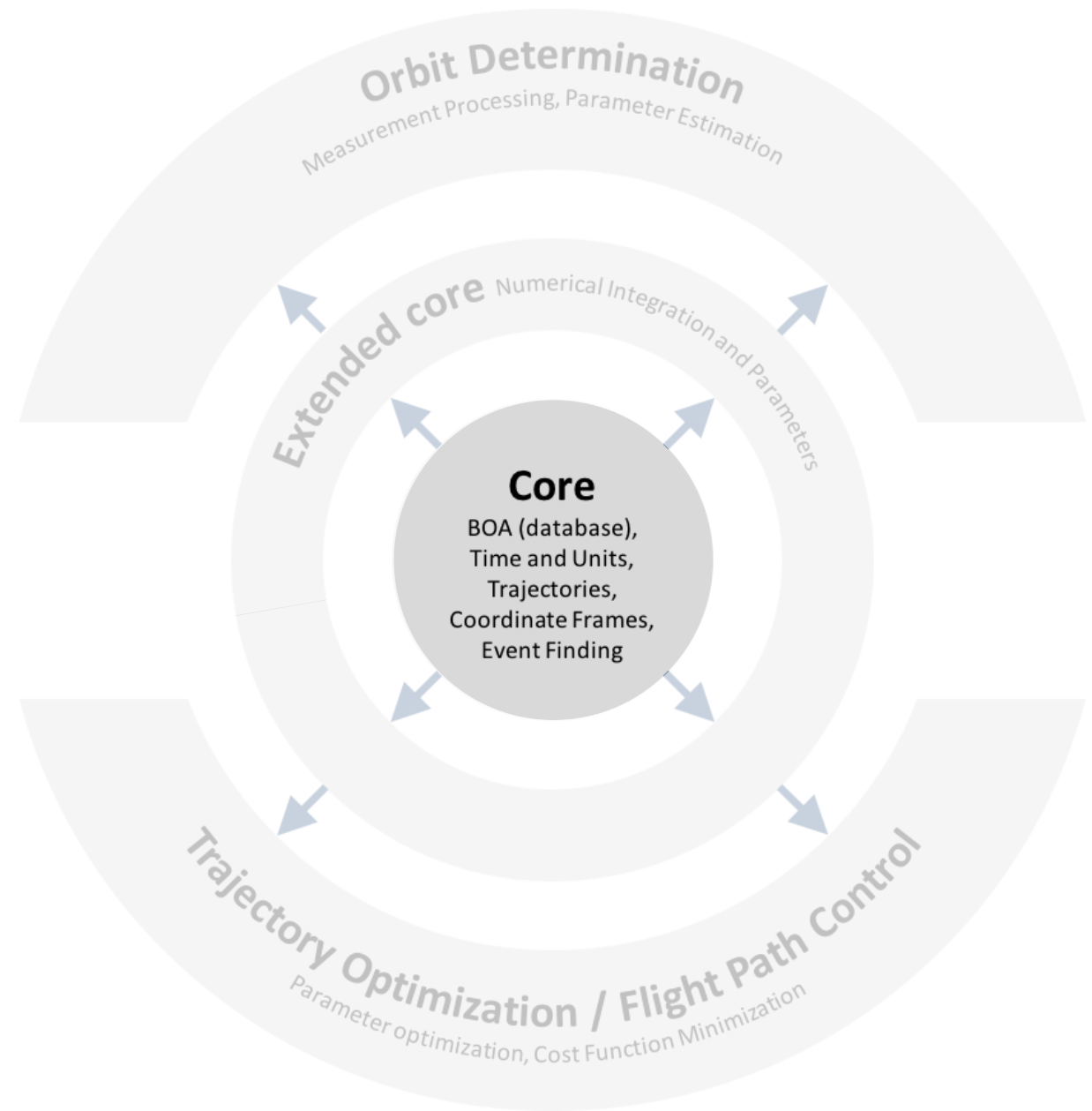


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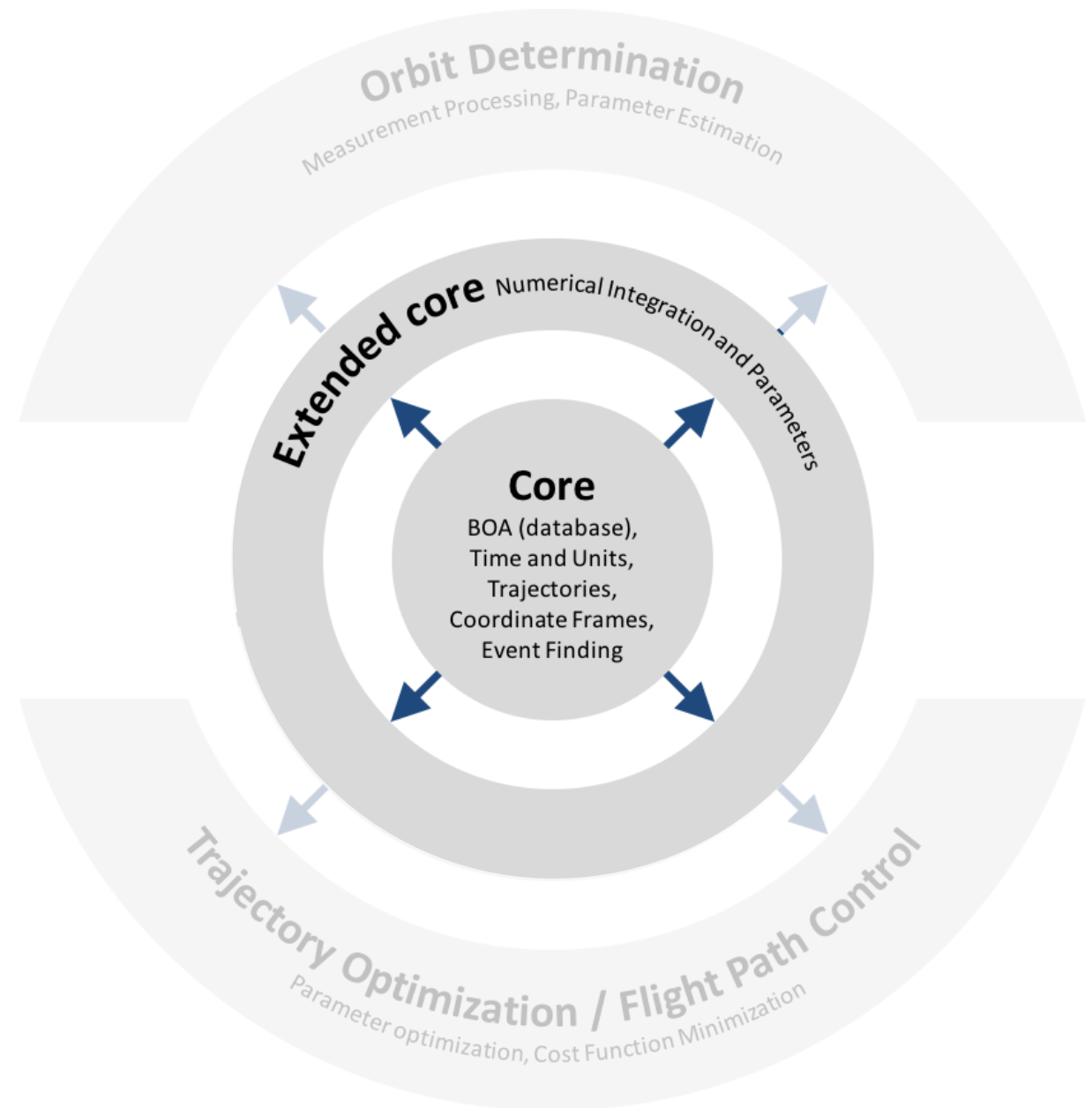


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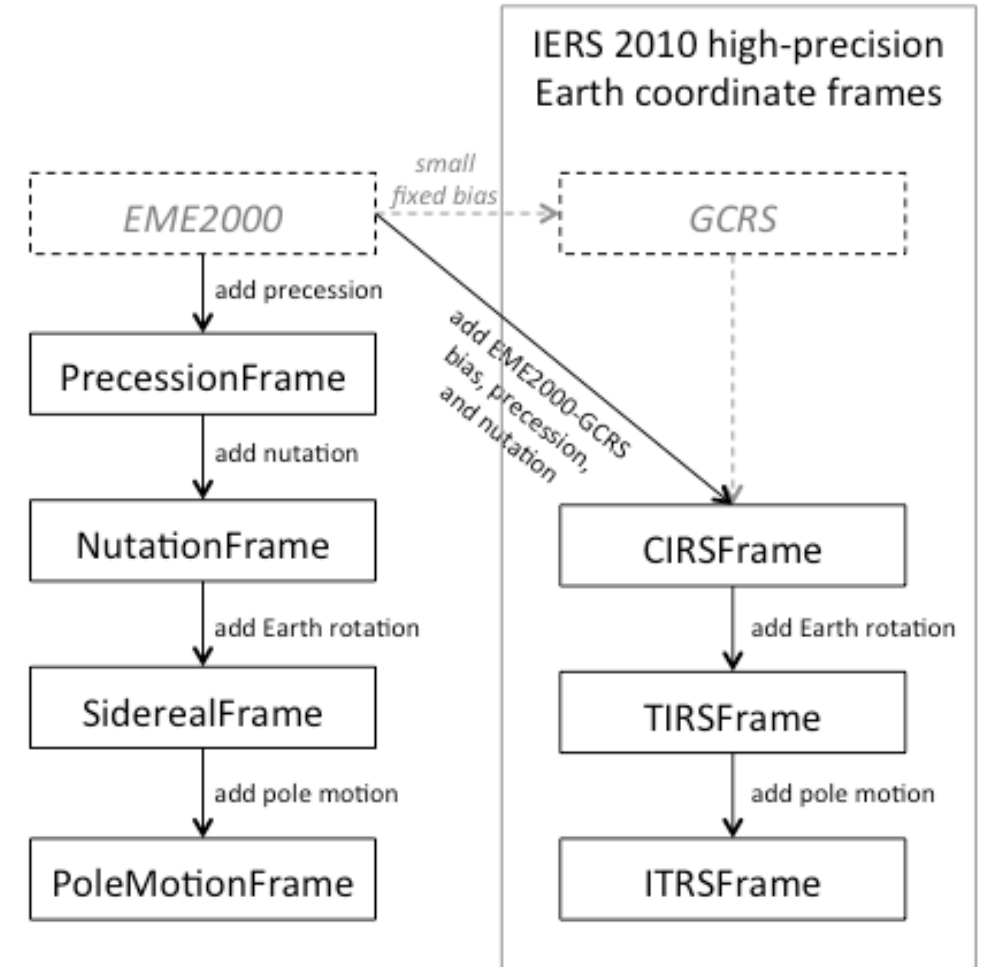
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Monte contains **high-precision Earth fixed coordinate frames** (Moyer and IERS formulations), and **Earth tracking station corrections** (plate motion, pole tide, solid tide, more).



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File Type	Description
EOP EOP2	Earth Orientation Parameter File IERS EOP File (Trk2-21)
DSN Media TDM Media	Ionosphere & Troposphere (Trk2-23) TDM Media Calibrations
DSN Tracking TDM Tracking UTDF Tracking GN Tracking GPS Tracking	Tracking data (Trk2-34) Tracking Data Message File UTDF tracking data file Ground Network UTDF files JPL FLINNR data files
JPL PSF JPL ITDF	Picture Sequence File (optical) In-situ tracking (SC to SC)



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Type	Description
Doppler	1/2/3 way Doppler observables
Range (DSN)	1/2/3 way range-unit observables
Range (phase)	2/3 way DSN phase observables
Range (mag)	1/2/3 way unit-length observables
Angle (DSN)	Az/El & X85/Y85 observables
Wide/narrow VLBI	DDOR observables
Accelerometer	SC acceleration observable
Torque	SC torque observable
Altimeter	SC-to-body altitude observable
Optical	Body center/landmark observables
Two-leg Doppler	SC-to-SC Doppler observable
Instant Range	SC-to-SC range observable
Instant Range Rate	SC-to-SC range rate observable
Instant Range Accel	SC-to-SC range accel observable
Phase GPS	GPS phase observable
Pseudo Range GPS	GPS range observable

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UD-factorized Batch Kalman and **Square-root Information** Filters

Estimation of **dynamic** (time varying), **bias** (time invariant), and **stochastic** (piecewise-continuous) parameters.

Include uncertainty for non-estimated bias parameters (“**consider** parameters”)

Current state (all parameters referenced to new batch epoch) and **pseudo-epoch state** (dynamic and bias parameters are referenced to the initial filter reference epoch; only the stochastic parameters are updated at each batch change) run modes

Map and transform uncertainty forward and backward in time.

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**CELESTIAL
MODELS**

Gm, Relativistic gamma & beta, Cap/disk/ring/point mascons, Constant inertia, Gas giant tide, Gravitational tide, Lense-Thirring, Planetary rings, Solar plasma density, Spherical harmonics & periodic corrections

**EPHEMERIS
MODELS**

Fixed offset trajectory, GPS broadcast ephemeris, Earth station trajectory, Equinoctial ephemeris, Hermite interpolation trajectory, Initial integration state, Offset trajectory group, Optimization control point, Planetary / small body ephemeris, Position & velocity state

**FRAME
MODELS**

IAU body-fixed pole & prime meridian, IERS2010 ITRS Frame & UT1 model, Mars angles, Nutation & precession, Offset frame, Pole motion, Polynomial frame & direction, UT1 time frame

**ATMOSPHERIC
MODELS**

Atmospheric drag, Exponential atmospheric density, Multiple atmospheric density, Mars-GRAM 2001 / 2005 / 2010, Venus-GRAM 2005



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**BURN
MODELS** Burn group, Finite maneuvers, Impulsive maneuvers, Isp thrust, Isp-pressure thrust, Named thrust, Polynomial thrust, Small maneuvers

**SPACECRAFT
MODELS** Mass, Accelerometer bias, Albedo pressure, Colatitude table shape, Cylindrical shape, Exponential accelerations, Flat plate shape, Parabolic dish shape, Polynomial state function, Polynomial torque, Solar pressure, Spacecraft bus shape, Spherical shape

**MEASUREMENT
MODELS** Ionosphere media delay, Troposphere media delay, Measurement bias, Optical navigation camera, Optical navigation picture, Optical phase bias, Quasar set, Star catalog, Polynomial clock offset, Polynomial frequency history

**MATH
MODELS** Fixed direction, Generic user defined polynomial, Harmonic table shape, Monomial, Named direction, Polynomial with trigonometric functions, Polynomial with exponential functions, Table-interpolated acceleration manager, Periodic accelerations, Polynomial accelerations



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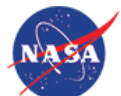
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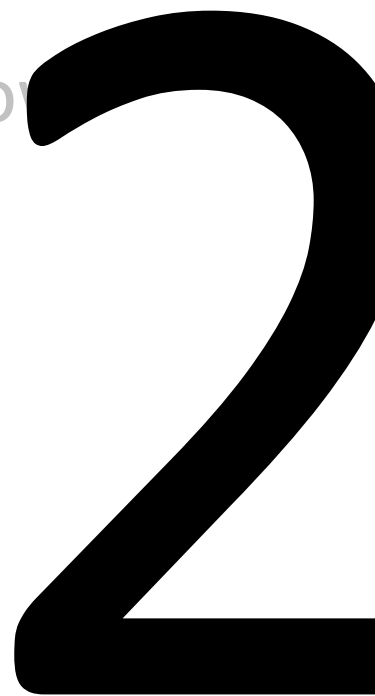
Monte's **UI System** brings all these capabilities together through the proven “Lock, Update, Run” method of OD operations.

#1 LOCK Define the base astrodynamic models to be used in flight and compile them into a **lockfile**. Changes to this file are infrequent and under tight configuration management.

#2 UPDATE Copy the lockfile to the local analysis directory. Apply updates to the copied lockfile as appropriate for the individual solution. The actual lockfile remains untouched by the local updates.

#3 RUN Run the analysis to completion using Unix-like command line tools.





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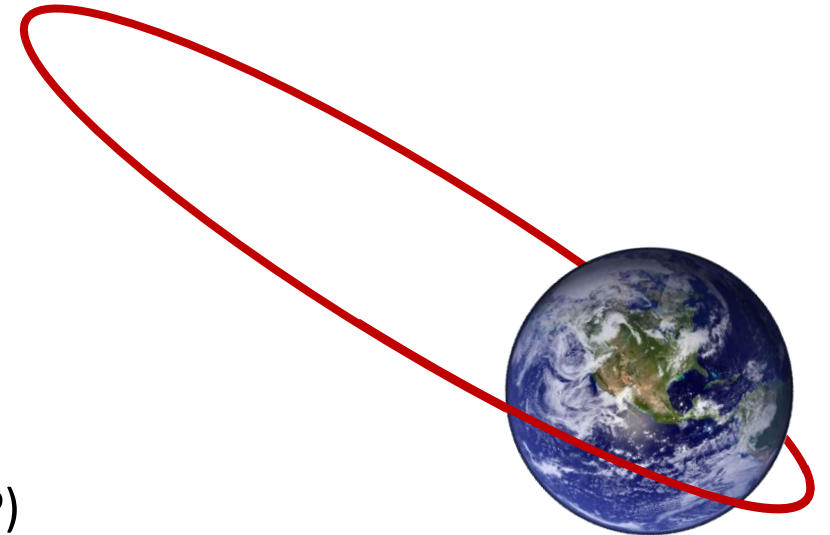


ORBITER CONFIGURATION

DESCRIPTION *Navigate closed orbit around a center planetary or satellite body.*

FOUNDATIONS
Atmosphere model and high-precision gravity field for center body
High-precision Earth station locations and associated models
2-Way Doppler and range
Spacecraft shape model for SRP and atmospheric drag
Impulsive and finite burn maneuvers

SPECIALIZATIONS
Data-driven predictive atmosphere model (used on **SMAP**)
Interpolated atmosphere model e.g. Mars-GRAM (used on **MAVEN**)
Automation of OD processing (used on **MRO**)



CRUISE CONFIGURATION

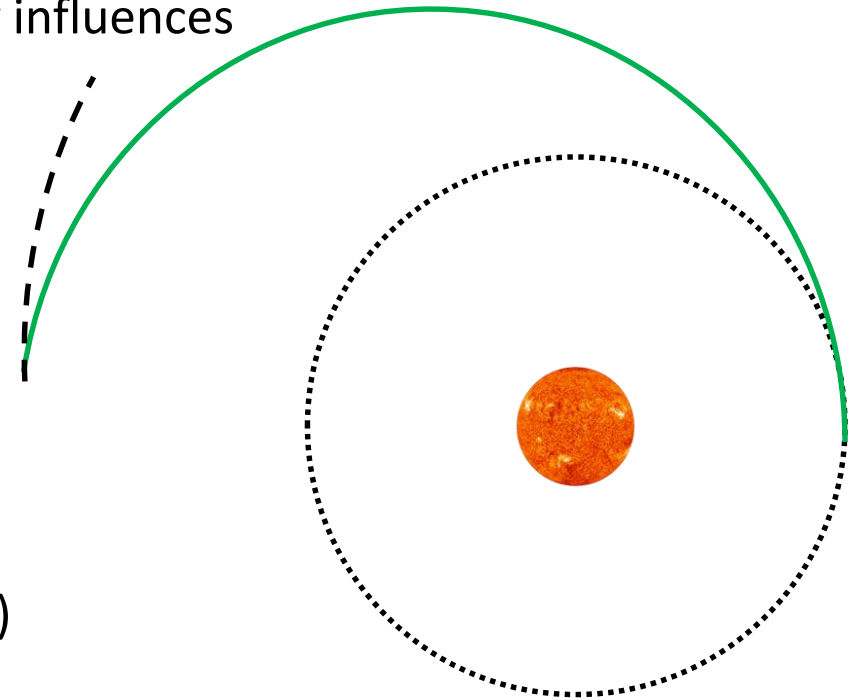
DESCRIPTI *Navigate interplanetary space, possibly with gravity-assist encounters.*

ON
FOUNDATI Point masses and ephemerides of significant third-body influences

ON B-Plane targeting
Gravity fields for encounter bodies

- Earth Station locations
- DDOR, 2-Way Doppler and range
- SRP modelling
- Impulsive and finite maneuvers

SPECIALIZATIONS Rapid switch to Orbiter Configuration (used on **MAVEN**)
OpNav on approach (used on **New Horizons Pluto**)
3-Way Doppler and range (used on **New Horizons Pluto**)
EDL interface and mapping to direct descent body (used on **Hayabusa & MSL**)

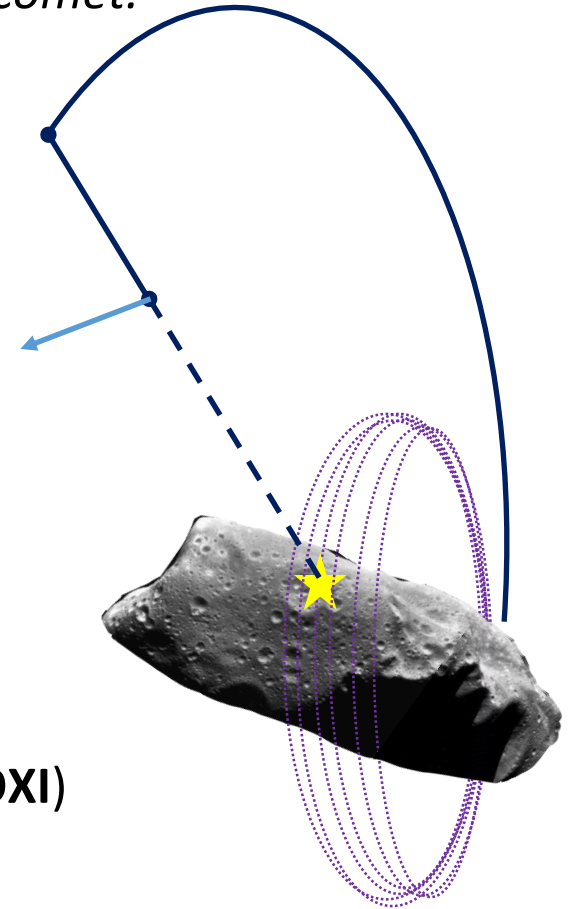


IRREGULAR BODY CONFIGURATION

DESCRIPTION *Navigate near an irregularly shaped body such as an asteroid or comet.*

FOUNDATIONS
ON Harmonic, polyhedral, or mascon gravity field
ON OpNav observables
Estimation of body ephemeris, pole and rotation
Gm and ephemerides for third-body influences
Earth Station locations
2-Way Doppler and range, DDOR
SRP modelling Impulsive and finite maneuvers

SPECIALIZATIONS
ONS Landmark processing (used on **Dawn**)
Comet outgassing model for ephemeris estimation (used on **EPOXI**)
Moving atmosphere to model comet coma (used on **Rosetta**)
6-DOF integration of body ephemeris (used on **Rosetta**)



TOUR CONFIGURATION

DESCRIPTI *Navigate a gravity-assist enabled tour of a gas-giant satellite system.*

FOUNDATIONS

ON Gravity fields for flyby bodies
Encounter-to-encounter OD arc segmentation

B-Plane targeting

Earth Station locations

2-Way Doppler and range

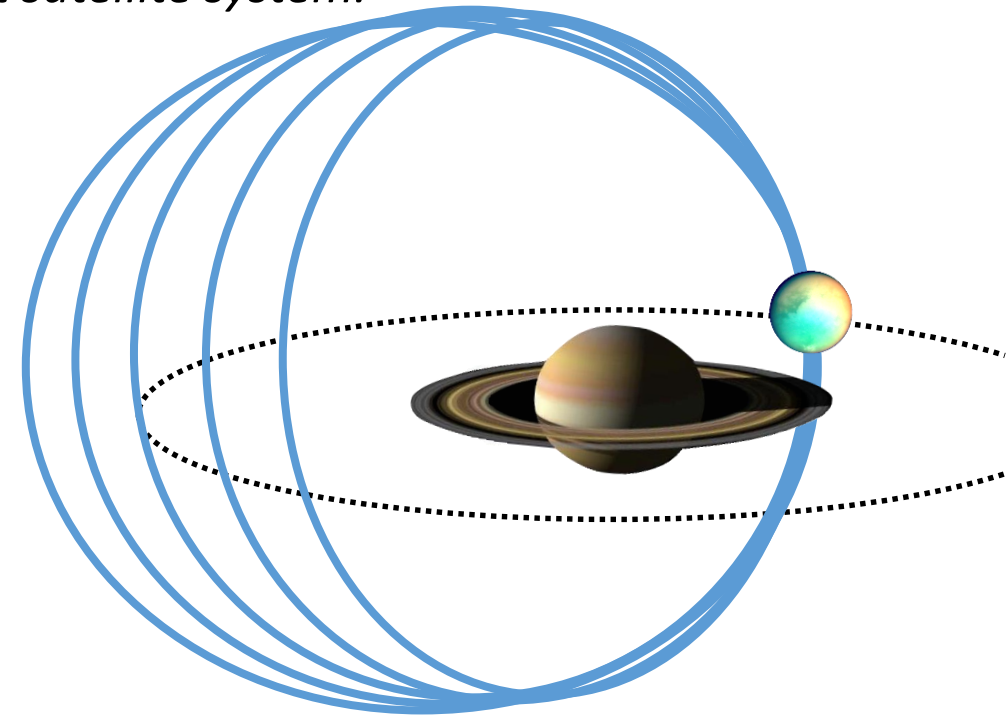
SRP modelling

Impulsive and finite maneuvers

SPECIALIZATI Satellite atmosphere modelling (used on **Cassini**)

ONS Estimation and integration of satellite system ephemerides (used on **Cassini**)

Ring mass modeling and estimation (used on **Cassini**)



MONTE IS AVAILABLE FOR LICENSING.

Visit montepy.jpl.nasa.gov or email mdn_software@jpl.nasa.gov for more information.

<i>Monte Design and Project Edition Capability Matrix</i>			Design Edition	Project Edition
Python UI for interactive work and application development			✓	✓
General astrodynamic analysis (instrument observation planning, coverage analysis, etc)			✓	✓
Trajectory Design and Optimization (conic, three body, fully integrated)			✓	✓
Pre-mission flight analysis (OD covariance, statistical maneuver analysis)			✓	✓
Parallel processing engine			✓	✓
Scriptable, 3D trajectory visualization			✓	✓
Suitable for classroom use			✓	
Export controlled (ECCN 9D515)				✓
Flight Operations (Orbit Determination, Flight Path Control)				✓



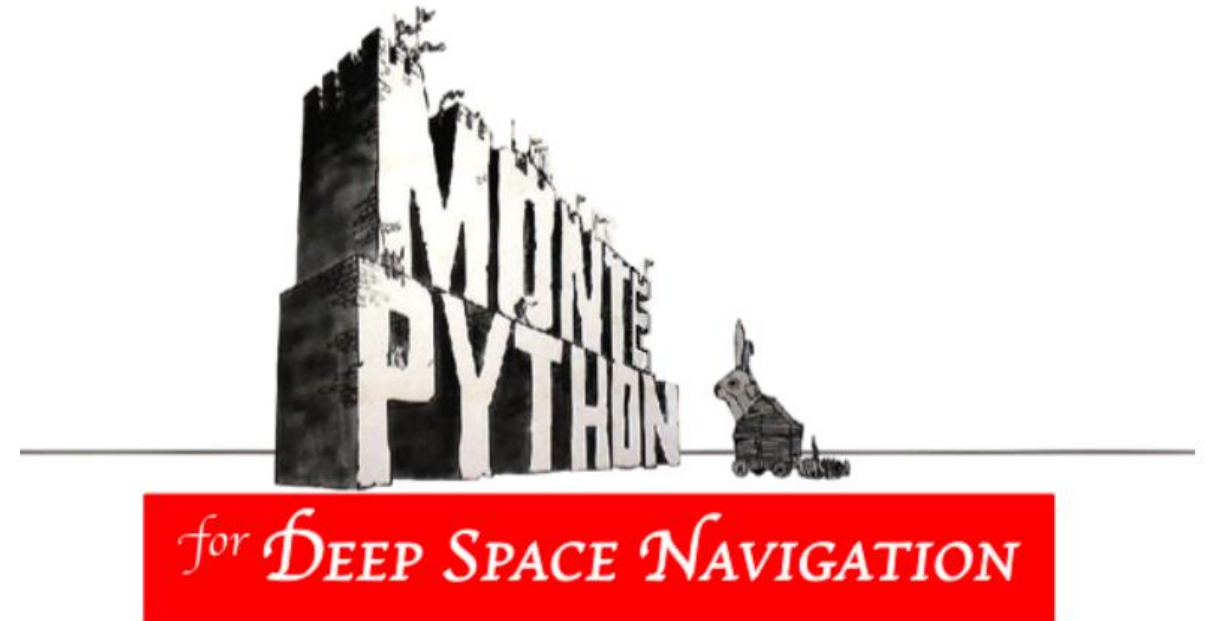
SPECIAL THANKS TO...

NASA's Multidisciplinary Design and Analysis (MDA) program office for sponsorship.

JPL Flight Missions (Phoenix, MSL, Cassini, MRO, Juno, Dawn, MAVEN, SMAP)

The Monte development team (William Taber, Theodore Drain, Scott Evans, James Evans, Michelle Guevara, William Schulze, Richard Sunseri, Hsi-Cheng Wu)

THANK YOU, ANY QUESTIONS?



Visit montepy.jpl.nasa.gov or email mdn_software@jpl.nasa.gov for more information.